A Portable ECG Signal Monitor and Analyzer

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***Abstract*—In recent years, because of the popularity of the computer, more and more people use the computer every day. For people usually forgetting that they need to take a rest during long time of using computer, they made themself in the fatigued state. The fatigued state could be evaluated by electrocardiogram(ECG). This article developed wireless ECG signal measurement and acquisition system. The system integrates ECG signal acquisition and bluetooth modules and the National Instruments LabVIEW software.ECG signal can be analysed to obtain heart rate, heart rate variability (HRV) , respiratory rhythm, the activity of the sympathetic and parasympathetic of autonomic nervous system. This system uses the wireless transmission technology of the Bluetooth to connect with computer. Therefore, the system can record the ECG signal of user while he using the computer or walking free around the computer. National Instruments LabVIEW analyses the physiological signal, displays and stores data in the computer. User can operate the system for monitoring his physiological signal and understanding his health very easily.**

Keywords-Bluetooth; ECG; Labview,HRV

I. INTRODUCTION

Electrocardiogram(ECG) can be used to monitor the heart activity and diagnose the heart disease. ECG is a type of non-invasive physiological signals. However the traditional ECG measurement device, which always has three or more electrode lines with the electrodes, is expensive and bulky. Because the electrodes must be pasted on human body when measuring ECG signal, it restricts the range of activities and it is complicated for self-examination when using traditional ECG measurement device.

ECG signal not only can be used to evaluate heart rate, but also can be used to analyse heart rate variability (HRV). Table 1 shows the descriptions and definitions of HRV measurement terminology. Through HRV analysis, we obtain the variety of the activities of sympathetic and parasympathetic nerves of the person, i.e. the situation of autonomic nervous system.

TABLE I.

DESCRIPTIONS AND DEFINITIONS OF HRV MEASUREMENT TERMINOLOGY [1]

Measure	Description
SDNN	The standard deviation of all normal-to-normal RR intervals
Total power (TP)	All variation in RR interval within the measured frequency bands
Low-frequency (LF) spectral power	Variation in RR interval 0.04–0.15 Hz.
High-frequency (HF) spectral power	Variation in RR interval 0.15–0.40 Hz.
Normalized LF spectral power (LFnu)	The proportion of spectral power from 0.04 to 0.15 Hz which is in the LF calculated by LF/(TP–VLF).
Normalized HF spectral power (HFnu)	The proportion of spectral power from 0.15 to 0.40 Hz which is in the HF calculated by HF/(TP–VLF).
Very low-frequency power (VLF)	The amount of variance of power in the heart's rhythm explained by periodic oscillations of heart rate at a frequency of 0.0033–0.04 Hz.
LF%	The spectral power in the LF band as expressed as a percentage of VLF, LF and HF.
HF%	The spectral power in the HF band as expressed as a percentage of VLF, LF and HF.
LO or SNS indicator	Harmonic spectral power in the frequency of 0.0–0.15 Hz.
HI or PNS indicator	Harmonic spectral power in the frequency of 0.15–1.0 Hz.

We will simplify ECG system, and make the system be a household device. The new device combines bluetooth wireless transmission, enables notebook and desk-top computer to support family members observing their physiological signal on the screen, evaluate their health, and record the result when they are being used.

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II. HARDWARE DESIGN

A. Structure of the system

Hardware system consists of ECG amplifier module, microcontroller ATmega32L and Bluetooth module as shown in Fig.1. The ECG signal is amplified via the ECG amplifier module. The analog to digital converter(ADC) provided by the ATmega32L converts the ECG signal to digital data. The ECG signal was transmitted to the computer by utilizing the Bluetooth module. The computer uses National Instruments LabVIEW to analyse and display after ECG signal received.

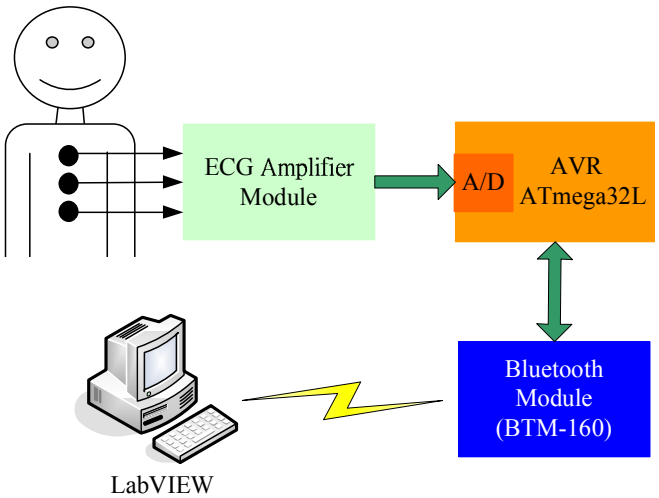

Figure 1. The system structure

B. ECG Signal Amplifier Module

The ECG signal is measured by the human surface electrode. Its amplitude ranges about from 1mV to 3mV, and the frequency ranges from 0.05Hz to 150Hz. For receiving correct ECG signal, the ECG signal must be amplified by about 1000 times. Fig.2 shows the ECG signal amplifier module structure. The AD623 is made for the pre-amplifier. The AD623 is an integrated single supply instrumentation amplifier that delivers rail-to-rail output swing on a single supply[2]. The notch filter eliminates the 60-Hz noise of ECG signal. Because the ECG signal ranges between 0.05Hz to 150Hz, the ECG module needs a bandpass filter to remove the high-frequency noise, and amplify the ECG signal again.

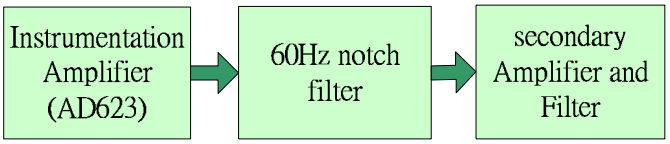

Figure 2. ECG signal amplifier module structure

C. AVR ATmega32L

In order to transmit ECG signal from ECG module to the Bluetooth module. The first step is to digitize the ECG signal. The traditional ECG measurement system can be reduced to a microchip with ECG and Bluetooth. Because ATmega32L has 8-channel 10-bit A/D converter, the system do not need a A/D converter chip. The operating voltage of ATmega32L is 2.7-5.5V, so the system can use the battery to supply power. The ATmega32L utilizes serial port to transmit the digitized signal to the Bluetooth module, and its baud rate sets up 115200bps.

D. Bluetooth Module

Bluetooth is a low power, low cost and low complexity technology that supports point-to-multipoint data transfer. In this system, we used a BTM-160 bluetooth module that is produced by Rayson. BTM-160 has the following features:

- The module is a Max.4dBm(Class2) module.
- Bluetooth standard Ver. 2.0 + EDR compliant.
- Low current consumption .
- Power supply 3.0V or 1.8V operation.
- Interface: USB,UART and PCM(for voice CODEC).
- Support for 802.11 Co-Exsitence.
- Small outline. Size: 14 x 12 x 2.2 mm.

III. SOFTWARE DESIGN

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine the order of program execution, LabVIEW uses dataflow programming, where the flow of data through the nodes on the block diagram determines the execution order of the VIs and functions[3].

LabVIEW softwave flow chart is shown in Fig3. In the beginning, we have received 5 minutes of ECG data. As the ECG data through the differential block, the program searches for P wave. Then, the program calculates R-R interval block and estimates the R-R interval. In the Fast Fourier Transform block, the program transforms time domain data into frequency domain, so frequency spectrum is obtained. Then, the HRV analyzer evaluates the HRV of the collected ECG data.

There are many different HRV metrics for short-term records (5min). The program calculates time domain metrics those are SDNN, RMSSD, and SDSD as follows[4].

$$\mathrm{SDNN} = \sqrt{\frac{1}{N-2}\sum_{n=2}^{N}[\delta(n)-\bar{\delta}]^2} \quad (1)$$

$$\mathrm{RMSSD} = \sqrt{\frac{1}{N-2}\sum_{n=3}^{N}[\delta(n)-\delta(n-1)]^2} \quad (2)$$

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$$\mathrm{SDSD} = \sqrt{\frac{1}{N-3}\sum_{n=3}^{N}[\delta(n)-\delta(n-1)-\bar{\delta}_{\delta}]^2} \quad (3)$$

The program also calculates frequency domain metrics those are LF norm, and HF norm as following.

$$\mathrm{LF\ norm} = 100 \times \frac{\mathrm{LF}}{\mathrm{TP - VLF}} \quad (4)$$

$$\mathrm{HF\ norm} = 100 \times \frac{\mathrm{HF}}{\mathrm{TP - VLF}} \quad (5)$$

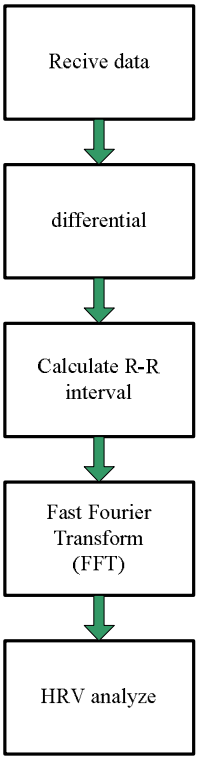

Figure 3. LabVIEW softwave flow chart

IV. RESULTS

Figure 4 shows that this system succeeded to record ECG signal. It is can view HRV values, heart rate, ECG signal, respiratory rhythm, and ECG spectrum.

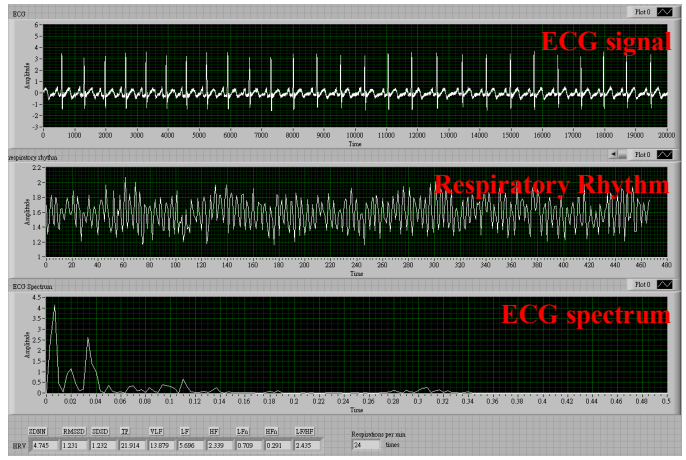

Figure 4. under the red light

V. CONCLUSION

We have designed and implemented a portale ECG recording system. Experimental results showed that the system can work stably.

This system has 5 key features:

- Portable by using Bluetooth Module.
- Convenient to connect with computer.
- Immediately analyse the ECG data.
- Momentarily display the result in the computer.
- Applicable to each family.

VI. ACKNOWNLEDGMENT

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